SPONTANEOUS VS INTENTIONAL ENTRAINMENT TO A MUSICAL BEAT

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ABSTRACT

We compared spontaneous vs intentional entrainment of rocking to a musical pulse. Participants sat in a rocking chair and rocked. As a cover task, in 13 of the 15 trials, they were asked to memorize five words and recall them after 45 seconds of rocking. In eleven of the trials, participants were exposed to a steady drum/cymbal beat. The tempo of the musical pulse either increased or decreased by 2 bpm on each trial (between 60 to 80 bpm) or was ordered randomly. Two baseline measurements of rocking tempo were taken at the beginning of the experiment and two more at the end.

Thirteen participants were instructed to rock at a comfortable pace (spontaneous condition); eighteen were instructed to rock with the beat (intentional condition). The motion was recorded at 60 Hz using a magnetic tracking system. We examined the synchronization of participants' back-and-forth movements in the rocking chair with the musical pulse. In the spontaneous entrainment condition, participants showed no evidence of synchronization, although they did rock faster with music than without it. In the intentional condition, some participants entrained to the actual beat, others doubled the beat, and others showed behavior that was more complex and not always stable. Overall, evidence for entrainment was not clear, but those in the intentional condition were clearly affected by the musical beat.

1. INTRODUCTION

When people listen to music they can often be seen tapping their feet, or moving their heads the beat (Blacking, 1995) and Western listeners often move in simple ratio integers with the music (e.g., 1:1, 2:1; Large, 2008). This type of entrainment to music is known as sensorimotor synchronization (Repp, 2005). Traditionally sensorimotor synchronization has been studied using the finger-tapping paradigm (Repp, 2005), however recent research has begun to use more naturalistic movements, such as conducting (Luck, 2002: see Repp, 2005 for a review). The current study introduces a new paradigm, rocking in a rocking chair, to examine how people entrain and are affected by a musical beat. Rocking provides a medium for measuring whole-body movements to music that allows comparison of spontaneous and intentional coordination with a musical beat.

The rocking chair paradigm has been used to measure spontaneous interpersonal synchronization by asking two people rock side by side (Richardson, Marsh, Isenhower, Goodman & Schmidt, 2007). When instructed to rock at a comfortable pace, participants exhibit relative coordination, i.e., move in and out of coordination with each other (Schmidt & O'Brien, 1997). Repp (2006) has shown that expert tappers (musicians with at least six years of training) also exhibit relative coordination with a musical beat during spontaneous tapping. When a distractor tempo was within 10% of another, target tempo, tappers were pulled into a state of relative coordination with the distractor tempo.

Styns, van Noorden, Moelants, and Leman (2007) examined how individuals walk to the sound of either a metronome or to music. They found that music sped up the walkers compared to the metronome and that people could generally synchronize their movements with either the music or the metronome. The current study used a steady tempo created by a drumbeat to examine how individuals in rocking chairs adjust their movements in the presence of a musical beat. We varied the tempo of the musical beat across trials in order to identify its effects. In addition, we asked some participants to rock with music. Others, we asked to rock at whatever tempo they found comfortable, without giving any specific instructions about how to respond to the music. To account for the music, participants performed a memory task as a cover and were told that we were interested in the effects of movement on memory.

A rocking chair (plus participant) has a natural period. We selected the range of musical tempi for the study so to the natural period of the chair fell in the middle of the range. We expected that, if participants synchronized with the music, they would do so at a 1:1 ratio with the musical beat for some music tempi. We anticipated that on some trials, participants might rock at rates that related simple integer ratios between rocking and music (Large, 2008). To identify such cases of complex synchronization, we computed a *music ratio* for each participant by dividing the tempo of rocking by the tempo of the musical pulse during each trial. A music ratio of "1" indicates that the mean rocking tempo matched the tempo of the music, a 1:1 ratio. A music ratio of "2" indicates a 2:1 ratio, i.e., rocking at double the tempo of the music. A ratio of "1.5" indicates a 3:2 ratio, i.e., three rocks with every two beats. Here, we limit our examination of the data to simple ratios.

2. METHOD

2.1 Participants

Thirty-one participants at the University of Connecticut were told that the purpose of the experiment was to test interaction of memory and movement.

2.2 Procedure and Materials

Participants were individually seated in a wooden rocking chair approximately three feet in front of a projection screen. Testing consisted of 15 trials during which the participant rocked for 45 seconds. Two *baseline trials* at the beginning and two more at the

end were conducted without music in order to provide a baseline measurement of each participant's natural rocking tempo. Eleven *music trials*, during which a steady drum/cymbal beat sounded in the background, assessed the affect of music on participants' rocking tempo. During the first baseline trial, participants simply rocked. During the second baseline trial, they also performed the cover task. The trial began with the appearance of five words on the screen which participants were asked to memorize. At the end of the trial, they were asked to recall the words. Participants continued to do the memory task during the subsequent 11 music trials. After the 11 music trials, a second pair of baseline trials were recorded without music. The first included the memory task and the second did not.

During the 11 music trials, the tempo of the music either increased or decreased by 2 bpm on each trial (between 60 to 80 bpm) or was ordered randomly The tempos used are shown in Table 1, along with the exact inter-beat interval (IBI) for each.

Tempo	IBI	Tempo	IBI
60	998.85	72	832.46
62	966.81	74	809.63
64	936.23	76	788.48
66	908.06	78	768.48
68	881.05	80	749.01
70	856.02		

Table 1: Tempi and Inter-response Intervals (IBI) of Music Stimuli

For the music trials, participants were either told to rock at a comfortable pace, i.e., with no instruction to rock with the music (spontaneous condition; $N = 11$) or to rock with the music as best they could (intentional condition; $N = 18$).

The motion of the rockers was recorded at 60 Hz using a magnetic tracking system (Polhemus Fastrak).

2.3 Analysis

The forward and backward motion of the chair followed a path that approximated a sinusoidal wave. To prepare these data for analysis, they were put through a low pass filter and then processed by a peak peaking program in Matlab. Both the peaks and valleys of the sine waves were selected and each was considered a response to the music. The rocking tempo for each trial was obtained by counting the number of peaks and valleys and converting this number to rocks per minute (by multiplying by 60 then dividing by the amount of time of spent rocking, 45 seconds).

A time series was obtained for each participant on each trial by measuring inter-response intervals (IRI) as the difference in time between each peak and valley. The IRI's were then divided by the IBI of the music for the trial (see Table 1) and averaged to provide the participant's music ratio for the trial. Values greater than "1" indicate a mean rocking tempo faster than the music; values less than "1" indicate a mean rocking tempo slower than the music.

To provide a baseline against which to assess the music ratios, we computed a *baseline ratio* for each participant for each trial. We used the second baseline trial, when the participants performed the memory task without music at the start of the experiment, to provide a measure of each participant's natural or preferred frequency of rocking. The IRI for the baseline was divided by the IBI of each music tempo to provide 11 baseline ratios for each participant. These ratios represent the hypothetical scenario in which each rocker in each trial was completely *unaffected* by the music and continued to rock at their natural frequency. A baseline ratio of "1" indicates that participants' own natural frequency was the same as the musical tempo. Values greater than "1" indicate that their natural frequency was faster than the musical tempo. Values less than "1" indicate their natural frequency was slower than the musical tempo.

3. RESULTS AND DISCUSSION

The results and discussion will be presented in two sections. The first will present the initial results from the spontaneous condition and the second from the intentional condition.

3.1 Spontaneous Condition

Figure 1 shows the mean music ratio for each participant during each trial. If participants matched the music tempo at a consistent ratio on each trial, their music ratios would have been consistent across trials. This did not happen. Instead, ratios generally decreased as tempo increased, indicating that rocking tempo remained constant, regardless of the music tempo. This suggests that participants did not synchronize with the music.

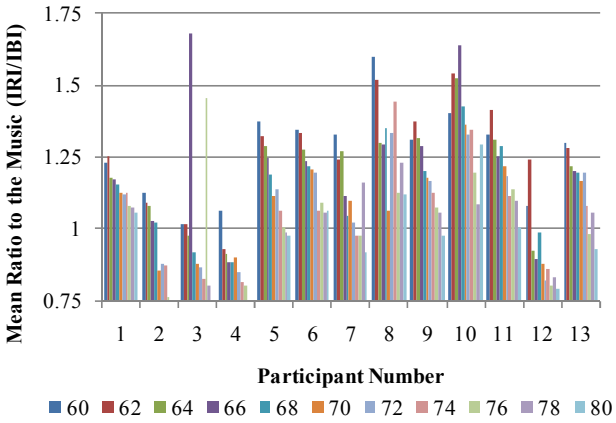

Figure 1: Mean music ratio (IRI/IBI) for each music trial and for each participant in the spontaneous condition. The x-axis represents each participant at each of the 11 music tempi. Music tempi are shown in the legend below the x-axis.

On some trials, however, when the period of the music was relatively close to the natural period of the rocker, participants might have exhibited some relative coordination. Future work will investigate the amount of relative coordination in trials by using analyses similar to those used by Richardson et al. (2007).

Despite the lack of synchronization to the beat, were participants' movements, nonetheless, affected by the beat? To investigate this question, we compared participants' music ratios with their

baseline ratios. Any difference between the two ratios would suggest that participants changed their movements because of the music. Mean music and baseline ratios are shown in Figure 2 as a function of the music tempo. Inspection of Figure 2 shows that music ratios were consistently higher than baseline ratios. The difference indicates that participants rocked faster with than without the music. A 2 (baseline ratio vs. music ratio) X 11 (musical trials) repeated-measures ANOVA (using the Greenhouse-Geisser correction) showed that the difference was reliable, $F(1, 12) = 8.33$, $p < .05$. On average the music ratio was higher ($M = 1.118$) than the baseline ratio ($M = 1.060$). The difference indicates that participants were affected by the music even though they may not have synchronized with it.

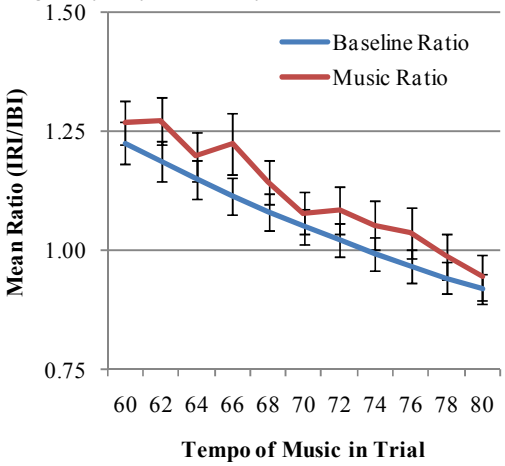

Figure 2: Mean music and baseline ratios in the spontaneous condition as a function of music tempo.

The effect suggests that rockers, like walkers (Styns et al., 2007), are influenced by the tempo of the music even when they are not instructed to synchronize with it. In fact, like walkers, participants on average sped up slightly from their natural baseline.

The analysis also confirmed the conclusion drawn from inspection of Figure 1, that rocking tempo did not change across trials as a function of changes in music tempo. In Figure 2, the same result is reflected in the fact that the slope of the functions representing the music and baseline ratios did not differ, $F(1, 120) = .76$, $p = .49$. If rocking tempo had changed with music tempo, the music ratio function in Figure 2 would be flat. Instead, the function for the music ratio parallels that for the baseline ratio, reflecting the fact that rocking tempo, like the baseline tempo, was unaffected as the tempo of the music changed across trials. Whether participants may have exhibited relative coordination in music trials where the music was close to their natural frequency remains to be determined.

3.2 Intentional Condition

The analyses for the intentional condition paralleled those for the spontaneous condition. Figure 3 shows the mean music ratio for each participant during each trial. As in the spontaneous condition (Figure 1), ratios generally decreased as tempo increased, indicating that rocking tempo remained constant, regardless of the music tempo. Unlike the spontaneous condition, however, the music ratios for several participants were relatively stable across trials, suggesting that they matched their rocking tempo to the music tempo and did so in a consistent fashion across trials. For example, participants 3 and 17 exhibited a ratio of close to 1:1 in most trials. Participants 2 and 5 generally exhibited a 2:1 ratio with the music (rocking twice as fast as the music). Other participants appeared to change the ratio at which they matched their rocking to the music across trials. For example, participant 1 maintained a ratio of 3:2 (1.5) for the first three trials and then transitioned to a ratio of 1:1 for one trial and then stayed relatively stable at a more complex ratio for the final trials. This participant seems to have maintained simple ratios to the music on some trials, but not others.

Unlike participants in the spontaneous condition, participants in the intentional condition appear to have rocked to the musical beat, as instructed, but to have done so in complex ways. Across all participants, we find that 53 of the trials (out of a possible 198) were within ±.05 of the two simplest ratios (1:1 or 2:1) with the music. When we compare this number to the possible number of trials that were within ±.05 of a simple ratio, extracted from the baseline ratio, we see only 36 of the 198 trials met the criterion. A chi-square test of independence showed that overall, participants were above chance levels in entrainment to simple ratios, $\chi^2(1, N = 396) = 4.19$, $p < .05$.

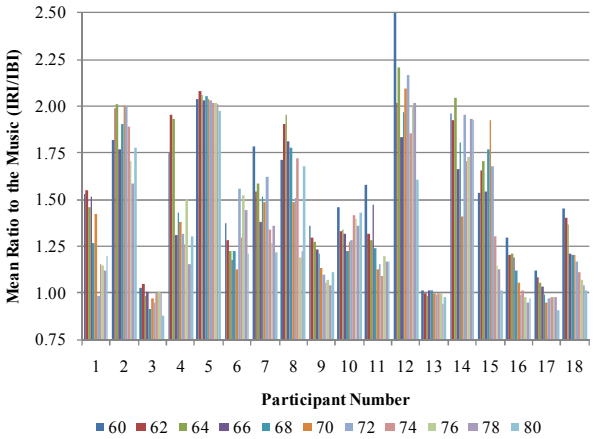

Figure 3: Mean music ratio (IRI/IBI) for each music trial and for each participant in the intentional condition. The x-axis represents each participant at each of the 11 music tempi. Music tempi are shown in the legend below the x-axis.

Next, to see if participants significantly deviated from their hypothetical baseline measure, we again conducted a 2 (baseline ratio vs. music ratio) X 11 (musical trials) repeated-measures ANOVA (using the Greenhouse-Geisser correction). Figure 4 shows a clear separation between the two lines showing that participants rocked significantly faster than their hypothetical baseline, $F(1, 17) = 10.74$, $p < .01$. In addition, the slope appears to be somewhat flatter than in the spontaneous condition (Figure 2), suggesting that the speed of rocking was influenced by the tempo of the music. Although the interaction was not significant, $F(1, 170) = .85$, $p = .58$, the analysis suggests that further examination of

individual participants may show that some adhered more to the tempo of music than others.

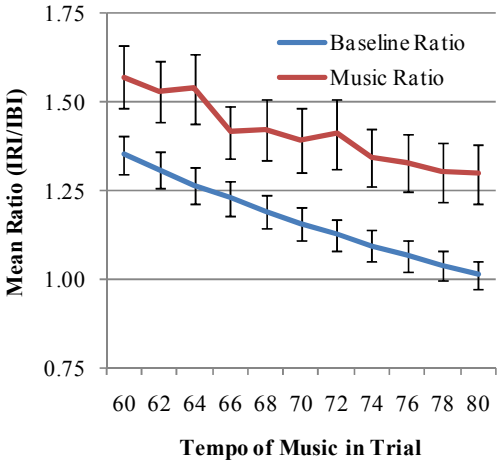

Figure 4: Mean music and baseline ratios in the spontaneous condition as a function of music tempo.

In summary, when participants intentionally tried to move with the music, they exhibited both simple and complex ratios to the music. As in the spontaneous condition, most participants in the intentional condition increased their rocking speed when exposed to the music and did so more dramatically than in the spontaneous condition.

4. GENERAL DISCUSSION

Participants in the spontaneous and intentional conditions were affected in similar ways by the music; however, participants in the intentional condition exhibited more entrainment with the music. In the intentional condition, some participants maintained simple ratios to the music and did so above chance levels. Even in the intentional condition, however, the amount of synchrony was not overwhelming. Instead, we see some complex behavior in relation to the music.

The rocking chair task appears to provide data that is more complex than the traditional finger-tapping paradigm, but may possibly reveal more of the more complex behaviors that people naturally exhibit when moving to music. Two factors may have contributed to the complex behavior exhibited by our participants. First, the natural period of a rocking chair constrained the movements of our participants much more severely than the natural period of participants' limbs in tapping tasks. Second, participants in this study were not the kind of "expert tappers" or musicians that are commonly studied in tapping tasks (Repp, 2006). Future work may include expert musicians in this paradigm and a comparison to the traditional finger-tapping paradigm to see if the behavior is similar.

Additionally, future work will examine the strength of the synchrony to the music across both the spontaneous and intentional conditions by using an oscillatory model similar to those created by Large (2008). Further, the data will be explored in terms of relative coordination to further examine how participants come in and out of phase with the musical beat.

5. REFERENCES

Blacking, J. (1995). *Music, culture, and experience.* Chicago: University of Chicago Press.

Large, E. W. (2008). Resonating to musical rhythm: Theory and experiment. In Simon Grondin, (Ed.) *The Psychology of Time*. West Yorkshire: Emerald.

Luck, G. (2002). Conductors' gestures: Perception of, and synchronization with, visual beats [CD-ROM]. In C. Stevens, D. Burnham, G. McPherson, E. Schubert, & J. Renwick (Eds.), Proceedings of the Seventh International Conference on Music Perception and Cognition (p. 638). Sydney: Causal Productions.

Repp, B. H. (2005). Sensorimotor synchronization: A review of the tapping literature. *Psychonomic Bulletin & Review*, 12, 969–992.

Repp, B. H. (2006). Does an auditory distractor sequence affect self-paced tapping? *Acta Psychologica, 121,* 81–107.

Richardson, M.J., Marsh, K.L., Isenhower, R.W., Goodman, J.R.L., & Schmidt, R.C. (2007). Rocking together: Dynamics of intentional and unintentional interpersonal coordination. *Human Movement Science*, 26(6), 867-891.

Schmidt, R. C., & O'Brien, B. (1997). Evaluating the dynamics of unintended interpersonal coordination. *Ecological Psychology*, 9(3), 189-206.

Styns, F., van Noorden, L., Moelants, D., & Leman, M. (2007). Walking on music. *Human Movement Science*, 26(5), 769-785.